REDUCTION OF PRIMARY ENERGY IN THERMO - HYDRAULIC INSTALLATION WITH ELLIPTIC SOLAR COLLECTOR

Fausto BOZZINI [(1)]***, Mircea MARINESCU*** [(2)]

[(1)] THERMO-TECHNICAL ENGINEERING APPLICATION, Italy
[(2)] UNIVERSITY "POLITEHNICA" OF BUCHAREST

Rezumat. *În această lucrare este prezentată optimizarea unei instalaţii energetice de încălzire constituită dintr-un cazan cu condensaţie echipat cu un cazan semi-rapid pentru producerea anuală a apei calde. În acest scop, s-au conectat în serie cu un colector solar eliptic cu acumulator. Combinaţia sistemului cazan - colector solar eliptic cu acumulator permite obţinerea absorbţiei maxime a celor trei componente ale radiaţiei solare în timpul unei zile la cel mai mic cost al instalaţiei. Rezultatele optimizării au condus la obţinerea unei energii zilnice maxime primite de la cele trei componente ale radiaţiei solare şi de asemenea la evitarea îngheţării în cazul reflexiei totale şi a fenomenului de supraîncălzire iarna, respectiv vara. Calculele termo-economice ale comparaţiei introduse, faţă de o instalaţie fără colector solar şi una cu colector solar eliptic cu acumulator scot în evidenţă reducerea cantităţii de combustibil ars şi economia obţinută pentru acest sistem.*
Cuvinte cheie: *instalaţie de încălzire / reducerea energiei consumate / optimizare termică /colector solar /energie solară*
Abstract. *In this paper, it is presented the optimisation of heat installation constituted of the condensing boiler equipped by the semi-rapid boiler for the annual production of sanitary warm water. For this purpose it was connected in series to an elliptic solar collector with incorporated accumulation. The combination of the system boiler - elliptic solar collector with incorporated accumulation allows to get the maximum absorption of the three components of the solar radiation in a full day with the least cost of installation. The results of the optimization lead to a maximum daily energy received from all tree components of the sun radiation, and also to avoid the freezing at total reflection and the superheating phenomenon in winter and in summer period, respectively. The thermo-economic calculation of introduced comparison, among an installation without solar collector and one with the elliptic solar collector to incorporated accumulation it underlines the reduction of burnt fuel and the economy gotten through this system.*
Keywords: *heating installation/reduction of energy/thermal optimization/solar collector/solar energy*

1. INTRODUCTION

The studied installation is constituted by a condensing boiler endowed by a semi rapid boiler with small accumulation of 14 lifters. The combined type of condensing boiler, it is appropriate for the heating and for production of warm sanitary water for the whole year, for a house of 120 m^2 lived by a family of 3 people. The boiler for production of warm sanitary water is connected to an elliptic solar collector with accumulation incorporated. The installation is analyzed appraising the reduction of the consumptions of methane burnt under operational conditions, at the end of the period of heating and in the six successive summer months.

In the big part of the installations, the solar integration happens through plane solar collectors or heat pipe. The heat transfer to a reservoir to accumulation with double serpentine, it to be destined to the solar circuit is filled by a mixture of water-glycol antifreeze. Through an electronic regulator the difference of temperature is valued (8-10°C) among the solar collectors and the reservoir to the purpose of to operate the pomp to transfer the heat to the boiler (L. Rocco and al., 1994). This system results to be still enough expensive, even if in these last years, the costs of installation have become more convenient because of the increase of the price of the oil. The amortization of such installations would result acceptable only with the help of government incentives.

Besides, for acceptable choices aesthetically (for example the position in adherence to the roof of the building), it often forces us to renounce big part of the available solar energy.

Therefore that the importance of a installation simple hydraulically is born, more economic but that at the same time both technologically and energetically advantageous.

The analyzed installation, has been carried out in a place of northern Italy to the latitude of L = 45°, and it is represented in *figure 1* where is been installed a condensation boiler equipped of integrated boiler connected to a solar collector with accumulation.

The *figure 1* shows the constitution of the installation: the condensing boiler 1) that it works to methane comprehensive of boiler of small capacity 3) equal to 14 lifters, with semi rapid heat exchange.

The solar collector 2), he is hydraulically connected to the boiler 3), in such way that the same receives water preheated by the solar collector always for the whole year.

When sanitary water is preheated, the elliptic solar collector receives cold water from the city net and the boiler receives water preheated by the solar collector. In this way, during the winter, the boiler will have the assignment to heat the water in the small boiler of the difference of temperature in comparison to the value of use (generally 40°C) obtained mixing the water flow exit of the same boiler. If the water temperature in the elliptic solar collector overcomes the temperature of the

[*] *COFRET'08, Juin 11-13, 2008, Nantes – France.*

distributed water, the condensing boiler is maintained power off through the command established by a probe of temperature that is immersed into the boiler. The elliptic solar collector with accumulation, in this case, is tilted of an angle of 30° (for Italy northern with latitude 45°). Its behaviour is as that of a common boiler, because, the heat accumulated by the volume of water (Vc = 135 l) it is stratified it toward the tall part of the solar collector. During a drawing continuous of the warm sanitary water, the cold water enters in the low part of the solar collector and it will have the tendency to remain in the low part without mixing him completely with the rest of the mass.

This allows to obtain some water to a constant temperature, with continuous drawing of around the 70% of his volume. From this moment, the temperature of the water of the elliptic solar collector decreases quickly.

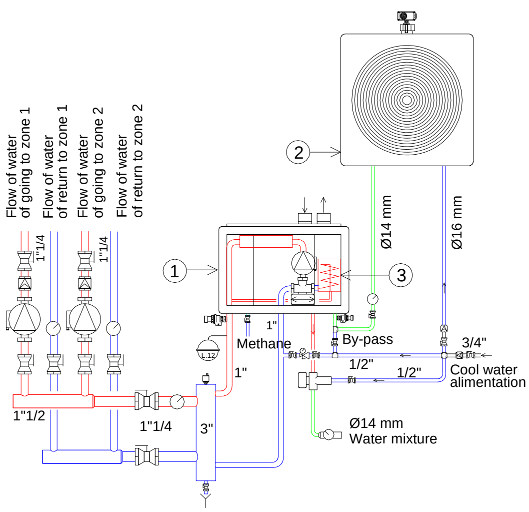

Fig. 1. Scheme of the installation of combined heating boiler-elliptic solar collector:
1 – the condensing boiler with equipped boiler of capacity 14 l;
2 – elliptic solar collector with accumulation;
3 – incorporated boiler.

To facilitate the understanding of the following economic analysis, introduces in *figure 2* the extrapolation of the scheme detailed of the whole boiler-solar collector.

Optimization annual of the consumptions of burnt methane is based on the following considerations. It is by today known and also suggested by the actually normative, that from the technical point of view, the installation of a boiler with accumulation to the instantaneous boiler place of one, allows to use a condensing boiler with smaller installed power.

Unfortunately but, in the moments in which the accumulation of water of the solar collector reaches the boiler with lower temperature of that of use, the condensing boiler it is forced to integrate the difference of temperature heating the whole content of water of the boiler. It is evident, that greater it is the capacity of the boiler, greater it will be the transitory of integration for its heating. In the transitory ones, the consumption of burnt methane will be wasted because in the following instant, rather short, the accumulation of water of the boiler could be still heated from the same solar collector.

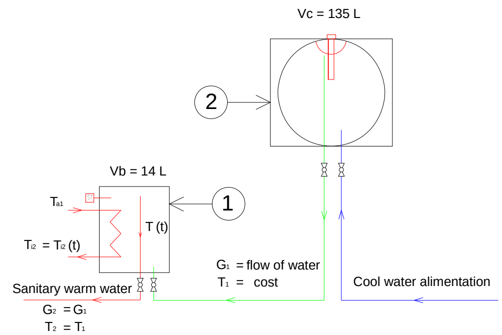

Fig. 2. Detail of the connection boiler-elliptic solar collector:
1 – boiler incorporated of 14 l in the condensing boiler,
2 – elliptic solar collector with accumulation of 135 l.

In the analysis of the installation of *figure 1* have been included, differently from the other systems of solar integration, some advantages that bring to a further reduction of fuel decreasing exactly the transitory aforesaid. The advantages can be reassumed this way:

- optimization of the transitory ones of integration using a condensing boiler equipped by boiler semi rapid of small capacity equal to 14 l connected in series to a elliptic solar collector with accumulation incorporated by 135 l. The assembly boiler-elliptic solar collector with accumulation represents the optimizing elements of the system.
- the accumulation of warm water is therefore sum of both the capacities (boiler from 14 l + solar collector from 135 l = 150 l). The purpose is that to always have the elliptic solar collector to a determined level of temperature. Besides the elliptic solar collector, exactly for his mass of elevated water, in winter reduces notably the possibility of freezing and summer doesn't succeed in reaching elevated temperatures of stagnation.
- the absorption of the diffused and reflected radiation is always exploited in the moments of low insulation.
- is been of fundamental importance the choice of a solar collector with accumulation with elliptic capturing surface, to the purpose to optimize the absorption of everybody of three components of the solar radiation, for whole day and in the winter periods with low solar altitudes. Mainly the absorption of the direct radiation is privileged, but also that diffused and reflected, that with the classical systems, it would be impossible to be exploited completely.

This elliptic solar collector unlike those plane, don't require neither the introduction of glycol antifreeze, neither the installation of a pomp of circulation. Then, is not even necessary the installation of an electronic regulator able to operate or to extinguish the pomp appraising the difference of temperature among the boiler and the solar collector.

Besides the elliptic solar collector demonstrate a superior temperature of that also distributed by the city net in the winter period. The ellipsoidal form of the transparent dome of absorbing ago, yes that the solar rays hit the surface with very low angles of incidence. We avoids so the loss of energy of the total reflection effect. The choice of this type solar collector is founded upon the following considerations: the solar ray in the impact on a transparent body can be reflected, refracted and absorbed, the angle of refraction together with that of incidence are tied up from the relationship (Kreith F. and al., 1978):

$$\sin\alpha/\sin\gamma = 1/n$$

where n points out the index of refraction of the metacrilat (elliptic absorption dome) in comparison to the air, where the index is considered unitary.

When $\alpha > \gamma$ then the medium transparent is more refractive than air and vice versa.

When $\alpha = 0$ then the ray doesn't suffer any deflection.

The index of refraction various with the wavelength of the incident ray and the single ghostly components comes refracted with different angles giving origin to the phenomenon of the dispersion. While in the passage from a medium less refractive optician (air) to a more refractive (metacrilat or glass) the luminous ray always comes refracted, not the contrary one is verified always. It exists in fact an angle limit, determined by the law of the refraction, over which a luminous ray rather than to resurface suffers a total reflection on the surface of separation of the two mediums (to see *figure 3*).

From the *figure 4*, there are deduced that in summer in the morning the plane solar collector is hit by the sun with an angle $\alpha = \alpha_{lim} = 42°$ progressively decrease until the hours 12.00 o'clock for then increase.

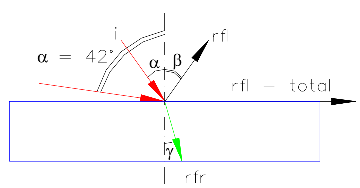

Fig. 3. Angles of incidence, reflection and refraction.

Considering $n = 1{,}5$ the index of refraction of the dome of metacrilat, comparable to that of the glass, the $\sin\gamma = 1$ ($\gamma = 90°$ when the angle of incidence $\alpha = 42°$). We deduce therefore that the ray is not able to resurface anymore, but it is situated on the parallel one to the transparent surface in condition of total reflection. The direct radiation is not captured. We analyze such phenomenon applied to a plane solar collector in the two cases summer and winter as represented in *figure 4* and then to the elliptic solar collector with accumulation in *figure 5* (Duffie J.A., and al., 1978)**.**

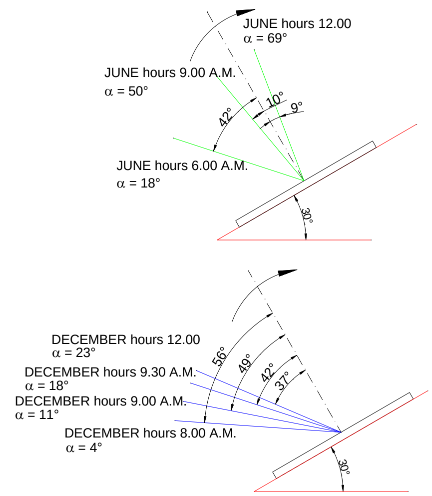

Fig. 4. Summer and winter solar excursion daily from the hours 6.00 at 12.00 o'clock – L = 45°.

The absorption of the direct radiation is acceptable into the whole day. In winter instead, the absorption has been being acceptable only for the hours 9.30 at 12.00 o'clock until the hours 14.30.

Out of these timeframe he reflects completely. In the case of the ellipsoidal solar collector the differences are underlined in *figure 5*.

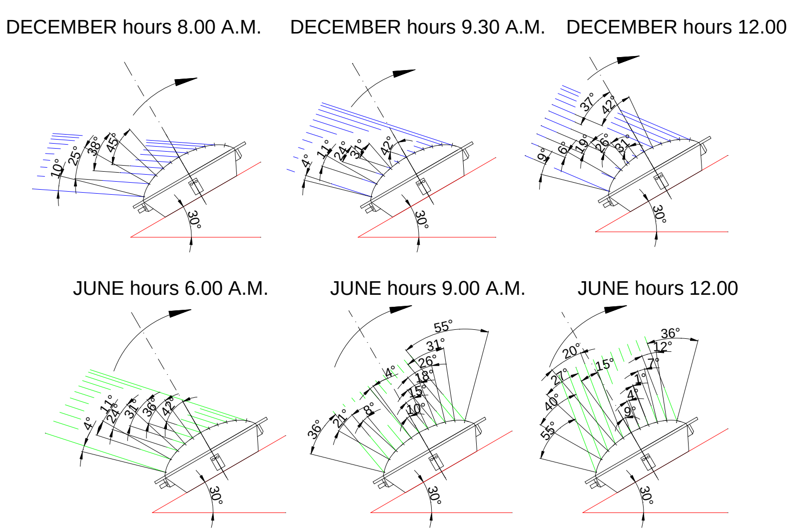

Fig. 5. Summer solar daily excursion from the hours 6.00 at 12.00 o'clock and winter from the hours 8.00 at 12.00 o'clock – L = 45°.

As it can be noticed in summer the elliptic solar collector, as for that plane, it absorbs the direct radiation in the whole day capturing very well and with small angles of incidence also during the first hours of the morning, for then to fully be exploited in the whole day. From 9.00 o'clock to 12.00 o'clock the total reflection to the edges of the elliptic solar collector is verified partially, but the phenomenon is compensated by the alternation of the incidents rays between the two semiellipsoids. In winter, the radiation is absorbed, even though partially interesting the absorbing surface, from the first hours of the morning until the evening, therefore for a superior number of hours. Out of these timeframe it reflects completely. The greater ampleness of the winter solar contribution facilitates to a best integration and a greater saving of fuel. Therefore is analyzed the saving of fuel using the combination between condensing boiler-elliptic solar collector with accumulation, in comparison to a installation deprives of solar collector.

2. THERMIC AND ECONOMIC ANALYSIS OF A CONCRETE CASE (**)

In the *charts I* and *chart II* are respectively introduced in the two installations without and with solar collector, the consumptions of methane in m^3, the specific costs in €/m^3 and in €/day, recorded in accordance with the paid invoices in the path of 5 separate periods marked in the aforesaid charts, through the numeration from 1 to 5. For a more suggestive comparative presentation of the consumptions of methane of the two types of installation (without and with collector) during these 5 periods, in the *figure 3* are introduced the diagrams of these consumptions.

Analysis has been effected on installation of *figure 1*, where to the condensing existing boiler 1) the elliptic solar collector has been connected to accumulation 2). The measured consumptions for the whole year in the two cases (*Progetto 2000,* Giugno 2001), re-presents the sum of the consumptions for the heating, warm sanitary water and of the kitchen. The electric energy consumption is due only to the installed pomp in the boiler and in the circuits of heating for allowing the circulation of the fluid in the installation.

The diagram of the consumptions is introduced on the following diagram of *figure 6*.

The data to our disposition are:

$V_k = 51$ m^3
$P_c = 33{,}6$ kW
$H_i = 34{,}4$ MJ/m^3
$\eta_g = 0{,}79$
$P_{p1} = 150$ W
$P_{p2} = 150$ W
$P_{pc} = 100$ W
$t_{fcc} = 295$ K - with elliptic solar collector
$t_{fsc} = 288$ K - without elliptic solar collector
$t_{ac} = 313$ K
c_c (2004) = 0,55 €/m^3
c_c (2005) = 0,57 €/m^3
$c_{el} = 0{,}085$ €/kWh
i = 2,64%
n = 15 years
C_i''=1.200,00 €

In the *charts III a, b* are underlined the numerical values of comparison calculated in the two cases with and without elliptic solar collector and the economic analysis.

Chart I. Consumptions of methane and specific costs in the installation without elliptic solar collector

	Progressive addition days	periodo of two-months utilization	consumption of methane m^3	cost €	days	specific cost of methane €/m^3	specific cost dailing €/day
1	90	01/01/04 - 31/03/04	1203	550,00	90	0,46	6,11
2	179	01/04/04 - 28/06/04	161	105,00	89	0,65	1,18
3	272	29/06/04 - 29/09/04	112	28,00	93	0,25	0,30
4	356	30/09/04 - 23/12/04	900	579,24	84	0,64	6,90
5	364	24/12/04 - 31/12/04	96	64,36	8	0,67	8,05
		total	**2472**	**1326,60**	**364**	**0,54**	**3,64**

Chart II. Consumptions of methane and specific costs in the installation with elliptic solar collector

	Progressive addition days	periodo of two-months utilization	consumption of methane m^3	cost €	days	specific cost of methane €/m^3	specific cost dailing €/day
1	90	01/01/05 - 31/03/05	1084	531,05	90	0,49	5,90
2	179	01/04/05 - 28/06/05	104	68,55	89	0,66	0,77
3	272	29/06/05 - 29/09/05	51	38,25	93	0,75	0,41
4	356	30/09/05 - 23/12/05	720	468,00	84	0,65	5,57
5	364	24/12/05 - 31/12/05	87	61,09	8	0,70	7,64
		total	**2046**	**1166,95**	**364**	**0,57**	**3,21**

(**) Installation of heating with elliptic solar collector with accumulation of the house in Via Bellinzago 48A - Novara-Italy.

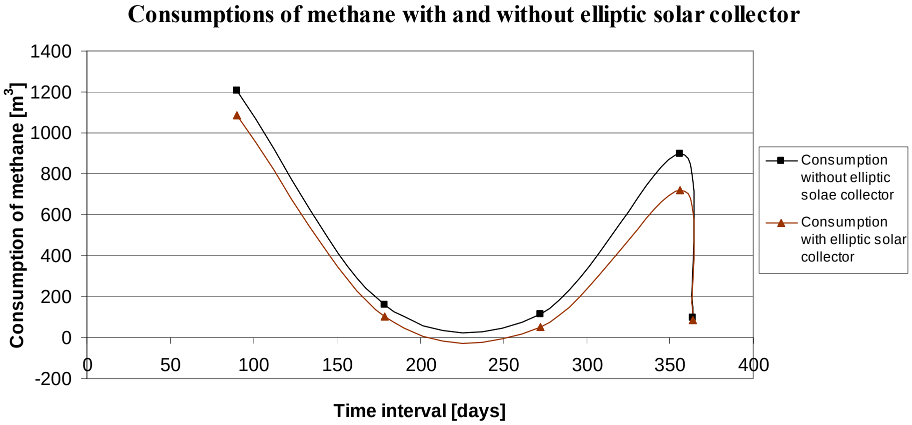

Fig. 6. Comparison of the consumptions with and without elliptic solar collector.

Chart III. Numerical values for both the choices with and without elliptic solar collector collector

Boiler condensing without elliptic solar collector				***Boiler condensing with elliptic solar collector***			
Summer period from 01/04/04 to 29/09/04				***Summer period from 01/04/05 to 30/09/05***			
Consumption of fuel due to the consumption of sanitary warm water							
V_{cse} =	$V_{cte}/4*6-V_k$ =	117,00	m^3	V_{cse} =	$V_{cte}/4*6-V_k$ =	25,50	m^3
Q_s' =	$V_{cse} \cdot H_i \cdot \eta_g$ =	3179,59	MJ	Q_s' =	$V_{cse} \cdot H_i \cdot \eta_g$ =	692,99	MJ
Q_{ts}' =	$2Q_s'$ =	6359,18	MJ	Q_{ts}' =	$2Q_s'$ =	1385,98	MJ
t_{summer} =	Q_s'/P_c =	26,28	h	t_{summer} =	Q_s'/P_c =	5,73	h
$t_{summer/day}$ =	t_{summer}/T =	0,15	h/g	$t_{summer/day}$ =	t_{summer}/T =	0,03	h/g
$\mathbf{m_{water}'}$ =	$Q_s'/c_p(t_{ac}-t_{fsc})$ =	**30426,72**	**l**	$\mathbf{m_{water}''}$ =	$Q_s'/c_p(t_{ac}-t_{fcc})$ =	**9210,37**	**l**
$\mathbf{m_{water/day}'}$ =	$Q_s'/c_p(t_{ac}-t_{fsc})/180$ =	**169,04**	**l/g**	$\mathbf{m_{water/day}''}$ =	$Q_s'/c_p(t_{ac}-t_{fcc})/180$ =	**51,17**	**l/g**
C_{se}' =	$V_{cse} \cdot C_c$ =	64,35	€	C_{se}' =	$V_{cse} \cdot C_c$ =	14,54	€
C_{si}' =	$V_{csi} \cdot C_c$ =	64,35	€	C_{si}' =	$V_{csi} \cdot C_c$ =	14,54	€
C_r' =	$(V_{ct}-V_{cse}-V_{csi}-2V_k) \cdot C_c$ =	1174,80	€	C_r' =	$(V_{ct}-V_{cse}-V_{csi}-2V_k) \cdot C_c$ =	1079,01	€
$\mathbf{C_t'}$ =	$C_{si}'+C_{se}'+C_r'$ =	**1303,50**	**€**	$\mathbf{C_t'}$ =	$C_{si}'+C_{se}'+C_r'$ =	**1108,08**	**€**
Electric energy consumption of the pomp winter+summer for the production of sanitary warm water							
P_{els}' =	$2 \cdot t_{summer} \cdot P_{elpc}$ =	5,26	kWh	P_{els}' =	$2 \cdot t_{summer} \cdot P_{elpc}$ =	1,15	kWh
$\mathbf{C_{els}'}$ =	$P_{els}' \cdot C_{el}$ =	**0,45**	€	$\mathbf{C_{els}'}$ =	$P_{els}' \cdot C_{el}$ =	**0,10**	€
Electric energy consumption of the pomp in winter for the period of heating							
Q_r' =	$(V_{ct}-V_{cse}-V_{csi}-2V_k) \cdot H_i \cdot \eta_g$ =	58047,94	MJ	Q_r' =	$(V_{ct}-V_{cse}-V_{csi}-2V_k) \cdot H_i \cdot \eta_g$ =	51444,17	MJ
t_{winter} =	Q_r'/P_c =	479,74	h	t_{winter} =	Q_r'/P_c =	425,16	h
$t_{winter/day}$ =	t_{winter}/T =	2,67	h/g	$t_{winter/day}$ =	t_{winter}/T =	2,36	h/g
P_{elr}' =	$t_{winter} \cdot (P_{p1}+P_{p2}+P_{pc2})/1000$ =	191,89	kWh	P_{elr}' =	$t_{winter} \cdot (P_{p1}+P_{p2}+P_{pc2})/1000$ =	170,06	kWh
$\mathbf{C_{elr}'}$ =	$P_{elr}' \cdot C_{el}$ =	**16,31**	€	$\mathbf{C_{elr}'}$ =	$P_{elr}' \cdot C_{el}$ =	**14,46**	€
$\mathbf{C_{elt}'}$ =	$C_{els}'+C_{elr}'$ =	**16,76**	€	$\mathbf{C_{elt}'}$ =	$C_{els}'+C_{elr}'$ =	**14,55**	€
$\mathbf{C_g'}$ =	$C_t'+C_{elt}'$ =	**1320,26**	**€**	$\mathbf{C_g'}$ =	$C_t'+C_{elt}'$ =	**1122,63**	**€**

Amortization for elliptic solar collector

ΔC_i =	$C_i' - C_i''$ =	-1200 €		
$\mathbf{\Delta C_g}$ =	$C_g' - C_g''$ =	**197,62 €**	$\Rightarrow$	**15,0 %**
i =		2,64 %		
PVa		12,29		
NPV =	$\Delta C_i + PVa(n,i\%) \cdot \Delta C_g$ =	**1228,81 €**		
for NPV = 0	**it is obtained:**			
PVa(n, 2,64%) =	$-\Delta C_i/\Delta C_g$ =	6,07	$\Rightarrow$	**6 < n < 7 years**
PVa(15, i%) =	$-\Delta C_i/\Delta C_g$ =	6,07	$\Rightarrow$	**i*=IRR =14%**

It is necessary besides to specify, that when the elliptic solar collector is installed, in the 6 summer months from 01/04/04 to 30/09/04, the production of warm sanitary water is practically free. The condensing boiler always results power off. Then, the difference of the consumption of fuel indicated in the *chart II* compared to *chart I*, simply is due to the use of the kitchen. We know therefore that this consumption corresponds to around 18 m^3/months for 3 people, that in three months corresponds at V_k = 51 m^3, the consumption of warm sanitary water is obtained subtracting this value from the data of the *chart II*. Admitting that such consumption is also identical in the devoid case of elliptic solar collector, it will come subtracted of the indicated consumption in *chart I* in same period. In the *chart III*, the cost of the solar collector also includes the manpower for the assemblage in comparison to the installation without solar collector. Subsequently in the same chart they underline it:

- the real saving of fuel equal to **15%**.
- the number of years of amortization "n", in the hypothesis that the investment is sustained with own funds and that the cost of the money is maintained constant in the time and equal to i = 2,64%, is obtained calculating at first the NPV, then the value of the parameter PVa in the hypothesis of a duration of the elliptic solar collector of n = 15 with i = 2,64%, extracting from the charts in literature of specialty (Bodt, 1969). The time of return of the investment corresponds at the year when the NPV annuls it
- the rate interns of efficiency i* = IRR

The form and the dimensions of the elliptic solar collector are introduced in the *figures 7a and 7b*.

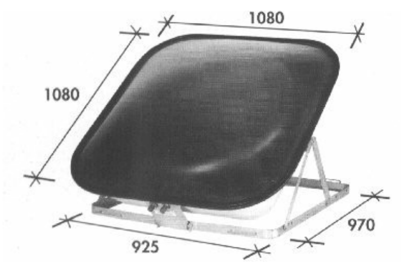

Fig. 7a. Elliptic solar collector assembled.

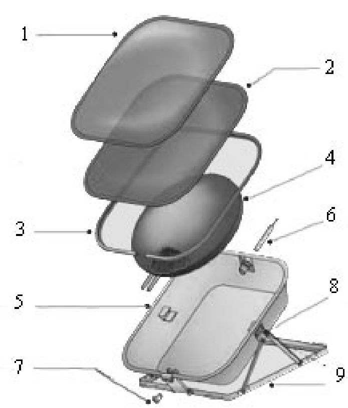

Fig. 7b. *1* – dome in metacrilat; *2* – double plate in metacrilat; *3* – gasket; *4* – reservoir 135 l; *5* – isolated container; *6* – magnesium anode; *7* – safety and non return valve; *8* – adjustable handle; *9* – adjustable support.

3. CONCLUSIONS

The value of the cash flows updated until to the useful life of the solar collector said also Net Present Value or NPV results positive. The maximum value of the interest that assures us the possibility to take money loan, without going in loss it corresponds to what the NPV annuls. Such interest is said IRR=i*, and results of 14%. The indicators NPV and IRR point out both that the investment is convenient. The pay back time of the investment represents the year when the elliptic solar collector is amortized and it is that to which corresponds the annulment of the NPV.

The investment is amortized among 6^o and the 7^o year. He doesn't need besides, to neglect the climatic variation of year in year. In fact the value of the degrees day in the period of heating in the year 2003/04 and in the year 2004/05, are respectively equal to 2286 GG and 2436 GG (Meteorological bulletin, 2004, 2005). The difference percentage of these two values is of 7%.

This shows, that the year 2004/05 have middle been more cold of the precedent and has influenced the consumptions of 5,8% in more.

Therefore, the energetic saving calculated of 15% must have increased of this percentage becoming equal to 19%. The annual saving of fuel is ranked around with that obtainable with the use of the plane solar collectors in the same case, but with the difference that economically the return of the investment decidedly results more quick. The elliptic solar collector demonstrates efficacy, for working into the whole year.

The calculations of this study could be more accurate, if in the future the consumptions of fuel were valued for an ampler time interval, considering the rate of inflation of the energetics products and the government incentives bonus.

Nomenclature

C_{elr}'	cost of electric energy of heating period without elliptic solar collector	[€]
C_{els}'	cost of electric energy of summer or winter period expense for utilising warm water without elliptic solar collector	[€]
C_{elr}''	cost of electric energy of heating period with elliptic solar collector	[€]
C_{els}''	cost of electric energy of summer or winter period expense for utilizing warm water with elliptic solar collector	[€]
C_g'	global cost of electric and thermic energy for case without elliptic solar collector	[€]
C_g''	global cost of electric and thermic energy for case with elliptic solar collector	[€]
C_i''	cost of the investment for installing the elliptic solar collector	[€]
c_p	specific heat of the thermovector fluid	[$MJ \cdot kg^{-1} \cdot K^{-1}$]
c_c	specific cost of fuel	[$€ \cdot m^{-3}$]
c_{el}	specific cost of elettric energy	[$€ \cdot kWh^{-1}$]
H_i	net heat value of fuel	[$MJ \cdot m^{-3}$]
m_{water}'	mass of warm water utilized in the case without elliptic solar collector	[l]
m_{water}''	mass of warm water mass utilized in the case without elliptic solar collector	[l]
P_c	thermic power of a condensing boiler	[kW]

P_{elp1}	electric power of the pomp of 1° zone	[W]
P_{elp2}	electric power of the pomp of 2° zone	[W]
P_{elpc}	electric power of the pomp of the condensing boiler	[W]
P_{els}'	electric power consumption of the pomp of boiler for production warm water without elliptic solar collector	[kWh]
P_{elr}'	electric power consumption of the pomps for production heating without elliptic solar collector	[kWh]
P_{els}''	electric power consumption of the pomp of boiler for production warm water with elliptic solar collector	[kWh]
P_{elr}''	electric power consumption of the pomps for production heating with elliptic solar collector	[kWh]
Q_s'	heating quantity needed for production of warm water without elliptic solar collector	[MJ]
Q_s''	heating quantity needed for production of warm water with elliptic solar collector	[MJ]
Q_{ts}'	heating quantity for whole year necessary for production of warm water without elliptic solar collector	[MJ]
Q_{ts}''	heating quantity for whole year necessary for production of warm water with elliptic solar collector	[MJ]
Q_{tr}'	heating quantity for whole year necessary for heating production without elliptic solar collector	[MJ]
Q_{tr}''	heating quantity for whole year necessary for heating production with elliptic solar collector	[MJ]
t_{fsc}	temperature of the water of entrance in the boiler without elliptic solar collector	[K]
t_{fcc}	temperature of the water of entrance in the boiler with elliptic solar collector	[K]
t_{ac}	temperature of the warm water in exit of the boiler	[K]
t_{summer}	operating time of the condensing boiler in summer period	[h]
$t_{summer/day}$	operating dailing time of the condensing boiler in summer period	[$h \cdot g^{-1}$]
t_{winter}	operating time of the condensing boiler in winter period	[h]
$t_{winter/day}$	operating daing time of the condensing boiler in winter period	[$h \cdot g^{-1}$]
T	six months summer period of the condensing boiler	[g]
V_{ct}	total volum of methane consumed for the whole year for production sanitary warm water and heating recorded to the paid invoices	[m^3]
V_{cse}	volum of methane consumed for production warm water in summer period recorded to the paid invoices	[m^3]
V_{csi}	volum of methane consumed for production sanitary warm water in winter period recorded to the paid invoices	[m^3]
V_k	volum of methane consumed for utilizing kitcken	[m^3]
PVa(n, i)	annual factor	[%]
NPV	net present value	[€]
IRR=i*	rate intern of efficiency	[%]

Greek symbols

η_g	season efficiency of the condensing boiler

BIBLIOGRAPHY

[1] Bodt G. *Direct costing*, Dunod, Paris, 1969.
[2] "*Bollettini meteo*" for years 2004 and 2005, Geophysical Observatory of Novara.
[3] Duffie J.A., Beckman W.A., *L'energia solare nelle sue applicazioni termiche*, Liguori ed. Napoli, 1978.
[4] Kreith F. and J.F. Kreider, *Principles of Solar engineering*, McGraw-Hill, New York, 1978.
[5] *Progetto 2000*, n. 20, Diagnosi Edifici e Impianti. Giugno 2001.
[6] L. Rocco, G. Cellai, *Fondamenti degli impianti di climatizzazione*, PEG, pag. 180-181, 1994.